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(54) **PROCEDE D'INACTIVATION DES VIRUS DU SANG ET DES PRODUITS SANGUINS**

(54) **PROCESS FOR INACTIVATING VIRUSES IN BLOOD AND BLOOD PRODUCTS**

(57) The invention is directed to a process for inactivating viruses in blood and blood products, comprising adding phenothiazine dyes to the solutions or suspensions to be treated and subsequently irradiating said phenothiazine dye-containing solutions or suspensions with light. The use of a very small concentration of phenothiazine dyes prevents any adverse effects on the plasma proteins. Inactivation is effected by direct irradiation of the blood bags. After irradiation the dyes may be removed from the blood. To this end the blood is passed over adsorbing agents.

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PROCESS FOR INACTIVATING VIRUSES IN BLOOD AND BLOOD PRODUCTS

Specification:

The invention is directed to a process for inactivating viruses in blood and blood products, comprising: adding phenothiazine dyes to the solutions or suspensions to be treated and subsequently irradiating said phenothiazine dye-containing solutions or suspensions with visible light in the range of the absorption peak of the respective dye, whereafter the blood or blood products may be passed over adsorbing agents for removal of the dyes.

It is known that photodynamic substances in combination with visible light or UV-light may have a virus inactivating effect. This is due to the affinity of these substances to external virus structures or to viral nucleic acid. Both facts apply to phenothiazine dyes. They react with the membrane structures of enveloped viruses and damage the same irreversibly under the action of light, whereby the virus loses its infectiousness (cf. Snipes, W. et al., 1979, Photochem. and Photobiol. 29, 785-790).

However, photodynamic substances also interact with viral RNA or DNA, especially with the guanine residues of these nucleic acids. When a dye/nucleic acid-complex has been formed it is stimulated by light energy so that denaturation of the nucleic acid and finally strand breakages result. Also, phenothiazine dyes induce the conversion of molecular oxygen to oxygen radicals which are highly reactive and may have various virucidal effects (cf. Hiatt, C.W., 1972, in: Concepts in Radiation Cell Biology, pp.57-89, Academic Press, New York; Oh Uigin et al., 1987, Nucl. Acid. Res. 15, 7411-7427).

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In contrast to other photodynamic dyes for virus inactivation, phenothiazine dyes such as methylene blue, neutral red and toluidine blue are of special interest because they can inactivate a number of viruses already in combination with visible light and, under certain conditions, even viruses that do not possess a lipid envelope, such as adenovirus.

In addition to that, methylene blue (MB) and toluidine blue (TB) for instance are themselves being used therapeutically, among other uses also as antidotes to carbon-monoxide poisoning and in long-term therapy of psychotic diseases. In this connection quantities of MB or TB much higher than those required for virus inactivation are used (1 to 2 mg/kg body weight) without any significant side effects. The low toxicities of MB and TB are also substantiated by data obtained from animal experiments.

However, since 1955 those of skill in the art have assumed that dye concentrations, especially in the case of toluidine blue, of less than 2.5 µM have only an insufficient virus inactivating effect (cf. F. Heinmets et al. 1955, Joint Report with the Naval Medical Research Institute, Walter Reed Army Institute of Research, U.S.A.).

In the previously described investigations of virus inactivation with phenothiazine dyes the dye concentrations are between 10 µM and 100 µM(Chang and Weinstein 1975, Photodynamic Inactivation of Herpes-virus Hominis by Methylene Blue (38524), Proceedings of the Society for Experimental Biology and Medicine, 148:291-293; Yen and Simon, 1978, Photosensitization of Herpes Simplex Virus Type 1 with Neutral Red, J. gen. Virol., 41:273-281). But at these concentrations there arises the draw-back that not only viruses may be inactivated but also plasma proteins, such as the coagulation factors. This is one of the reasons why phenothiazine dyes have so far not achieved any significance in the inactivation of viruses in blood and blood products.

It is the object of the subject invention to provide a process for inactivating viruses in which various kinds of viruses are killed by the use of phenothiazine dyes without any functionally detrimental effects on the plasma proteins. It is a further object of the invention that said process be of simple design, such that blood or blood products may be subjected to direct treatment in commercially available blood bags and the added dyes may be removed after processing if so desired.

The specified object is accomplished in accordance with the invention in that the phenothiazine dyes are used at a concentration of from 0.1 to 2 µM and irradiation is effected directly in transparent containers, such as blood bags, of the kind used for the collection and storage of blood.

The irradiation is performed either with daylight of sufficient intensity or with monochromatic light, preferably from a cold light source at a wavelength in the range of the absorption peak of the respective dye. Also, the following conditions should be observed for virus inactivation in blood plasma or plasma protein solutions: The operating temperature should be in the range of from 0 to 37°C, if possible from 4 to 20°C. The inactivating time ranges especially from 5 minutes to 5 hours, preferably from 10 minutes to 3 hours, and pH should be between pH 5 and pH 9, preferably between pH 6 and pH 8.

An essential advantage of the process according to the invention lies in its simplicity. F. Heinmets et al. (as specified above) describes a highly complex apparatus through which, for instance, blood plasma must be passed. Here, problems of maintenance and above all capacity arise. Surprisingly, it has now been found that substantially smaller quantities of dye are sufficient and that no complex technical apparatus is required for photoinactivation.

Unexpectedly, it has also been found that a non-enveloped virus, such as adenovirus, which could not be inactivated under physiological conditions in plasma, could be photosensitized by

a freezing/thawing step and could thus be inactivated. In this connection inactivation has been ascertained irrespective of the employed order of the freezing/thawing steps and the addition of the dye. Freezing here means a deep-freezing operation at temperatures of from approximately -20°C to approximately 80K. Normally, deep-freezing is carried out at temperatures below -30°C.

Virus inactivation may be carried out directly in blood or plasma bags although these are transparent only to a limited extent. It is merely necessary to add the dye. Then the bag inclusive of its contents is exposed to light, whereafter the respective product can be further processed.

Thus, the process can be carried out without any major technical effort and is excellently suited for integration in the processing flow of individual blood donations. The small quantity of the dye used may either remain in the treated fluid or may be removed by adsorbing agents.

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Example 1

Below, the dependence of photoinactivation on the concentration of methylene blue (MB) is shown for VSV in human plasma. Varying concentrations of MB were added to human plasma containing approximately 5 x 10^7 Plaque Forming Units (PFU) per ml of VSV. Control samples did not contain any dye. The sample volume was 0.5 ml. One control sample and a portion of the MB containing samples were irradiated with visible light for 4 h at room temperature; the others were stored in the dark for the same length of time. The light source used was a slide projector equipped with a halogen bulb of 150 W (Osram Xenophot). The distance between the slide projector lens, i.e. the light outlet and the samples was 30 cm in these and all further tests (with the exception of blood bag virus inactivation).

Following completion of irradiation, the virus titer was determined in all samples by means of a plaque assay. The indicator cells used were BHK cells. The test results are listed in Table 1.

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Samples	MB concentr. (µM)	Light	Virus Inactivation Factor
contr.1	0	+	4.8
contr.2	0	-	1
1	0.01	+	11.8
2	0.1	+	28.5
3	0.5	+	$>10^6$
4	1	+	$>10^6$
5	10	+	$>10^6$
6	50	+	$>10^6$
7	100	+	$>10^6$
8	1	-	1
9	10	-	5
10	50	-	11.8
11	100	-	95

Table 1: Inactivation of VSV in human plasma with and without illumination.
Exposure time: 4 h

The results of Table 1 show that the infectious titer of VSV was reduced by a factor of more than $6\log_{10}$ at a minimal MB concentration of about 0.55 µM. Significantly higher concentrations of the dye, from about 50 µM and up, resulted in a significant reduction in the VSV titer even without exposure to light.

Example 2

The following test confirmed virus inactivation at low dye concentrations.

In the presence of plasma and varying amounts of methylene blue in aliquots of 500 µl, VSV was irradiated overnight in a cold-storage room with the slide projector from a distance of 30 cm. Samples A to F were illuminated, sample G was not.

The results of this test are presented in Table 2. They show that under the above-mentioned conditions the VSV used was inactivated by a factor of more than $4\log_{10}$. This required 0.5 µM of methylene blue.

It is probable that the VSV titer had already been reduced by 1 to 2 logs by the overnight incubation at 4°C, which would explain the relatively low initial titer. However, this was not simultaneously tested in our experiment.

A comparison of A (exposed) and G (dark) shows that light alone evidently does not influence the infectiousness of the virus to any great extent.

Sample	final MB concentr. µM	Titer/200 µl	Inactivation factor
A	0	2×10^4	2.2
B	0.01	2.4×10^4	1.8
C	0.05	2×10^4	2.2
D	0.25	3×10^2	147
E	0.5	≤ 1	$\geq 4.4 \times 10^4$
F	1.0	≤ 1	$> 4.4 \times 10^4$
G	0	4.4×10^4	1

Table 2: Virus inactivation at low dye concentrations

Example 3

The photoinactivation of viruses in the presence of phenothiazine dyes depends on the exposure time. To find out what exposure times would be sufficient for photoinactivation of VSV, 106 Plaque Forming Units (PFU) per ml were suspended in plasma and illuminated as described for different times at 22°C. The results are listed in Table 3. It is evident that under the

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specified test conditions an exposure time of one hour was sufficient to reduce the infectious VSV titer by a factor of more than $6\log_{10}$.

Sample	Exposure time (min)	Inactivation factor
control	0	1
1	5	50
2	30	1666
3	60	$>10^6$

Table 3: Kinetics of the photoinactivation of VSV by MB

Example 4

A similar test was carried out in the presence of 1 µM of another phenothiazine dye, TB, instead of MB. The results listed in Table 4 show that effective inactivation of VSV can also be achieved by using TB.

Sample	Exposure time (min)	Inactivation factor
control	0	1
1	10	20
2	60	$>4 \times 10^3$

Table 4: Kinetics of the photoinactivation of VSV by TB

The inactivating effect of the phenothiazine dyes was also shown for herpes simplex virus (HSV) and for type 1 human immunodeficiency virus (HIV-1).

Example 5

HSV is also inactivated in the presence of methylene blue (1 µM). Table 5 shows the kinetics of photoinactivation of HSV by MB.

Sample	Exposure time (min)	Inactivation factor
control	0	1
1	20	35
2	60	1500
3	180	$>3 \times 10^4$

Table 5: Kinetics of the photoinactivation of HSV by MB

Example 6

A similar test was conducted with the AIDS virus HIV-1. The virus titer was 6×10^2 PFU/ml. MT4-cells were used as indicator cells. Table 6 shows that HIV-1 is apparently especially sensitive to photoinactivation: the virus titer was already reduced by a factor of more than 600 within the first 10 minutes.

Sample	Exposure time (min)	Inactivation factor
control	0	1
1	10	>600
2	60	>600
3	120	>600

Table 6: Kinetics of the photoinactivation of HIV-1 by MB

Example 7

There was no success in an attempt to inactivate non-enveloped viruses under the usual physiological conditions in the presence of 80% plasma. As an example of a non-enveloped virus, adenovirus was pre-incubated for a prolonged period of time (4°C, dark) in the presence of methylene blue (MB) dye, 1 µM. Then, irradiation was effected for 30 minutes with halogen bulbs (150,000 lx). There was no change in the infectiousness of adenovirus.

Sample	Pre-Incubation time	Dye	Virus titer (log10)
control	0 h	--	6.0
1	0 h	MB	6.0
2	1 h	MB	5.5
3	4 h	MB	6.0
4	24 h	MB	6.0

Table 7: Influence of the pre-incubation time on the photosensitization of adenovirus.

The virus titer was determined as TCID50 (calculation method "Tissue Culture Infectious Dosis" by Spearman and Kaerber). The virus was titrated on FL cells (defined cell line suitable for virus titration).

When toluidine blue was used under the same experimental conditions, there was also no reduction of the virus titer that could be detected.

To achieve inactivation of adenovirus, a freeze/thaw step (F/T) with deep-freezing to -30°C was incorporated in the test run. Here, the order of F/T and the addition of the dye (1 µM MB) was of secondary importance only. The samples were again irradiated using halogen bulbs, as described above. 120,000 lx were measured.

Sample	Preparation of Sample	Virus Titer (log10)
control	7.5	
A	F/T	7.0
B	F/T + 60 min irradiation	7.5
C	F/T + MB + 60 min pre-incubation + 60 min irradiation	2.5
D	MB + F/T	7.5
E	MB + F/T + 10 min irradiation	5.0
F	MB + F/T + 30 min irradiation	5.0
G	MB + F/T + 60 min irradiation	4.0

Table 8: Photosensitization of adenovirus due to an incorporated F/T step.
Virus titration was carried out as described in Table 7.

Example 8

The special problem when using high dye concentrations is in the immediate effect of these substances on plasma proteins. Therefore, the influence of different dye concentrations on the activities of coagulation factors was investigated in a further test.

Varying amounts of MB were added to human plasma (2-ml aliquots). The activities of the coagulation factors V, VIII and IX were measured immediately thereafter. As is evident from Table 9, said factors are inhibited in all three cases in dependence on the concentration of the dye, whereby the activities of the factors VIII and V are inhibited from about 10 µM and those of factor IX already from 2.5 µM. Consequently, at higher concentrations MB has a direct effect on the proteins, without need of the action of light.

Methylene Blue (µM/l)	Factor V E/ml	Factor VIII E/ml	Factor IX E/ml
0	0.80	0.38	2.0
1	0.76	0.41	1.9
2.5	0.78	0.41	1.6
5	0.74	0.38	1.45
10	0.54	0.35	1.20
20	0.44	0.28	1.10

Table 9: Influence of MB on the activities of coagulation factors

Example 9

However, it is not only the dye concentration used but also the exposure time which influences the activities of coagulation factors. This time-dependence has been determined for varying concentrations of methylene blue.

Human plasma (aliquots of 2 ml) received varying amounts of MB and was then exposed to light for 1 to 4 hours (as described in Example 1). Control samples were not subjected to photo-treatment. As is evident from Table 10, the activities of the three coagulation factors V, VIII and IX are inhibited in dependence on time and the concentration of the dye. Especially in the cases of factors VIII and IX higher MB concentrations and exposure times from 2 hours upwards cause an apparent increase in their thrombolytic activities.

Exposure time	MB Concentration µM/l	Factor V E/ml	Factor VIII E/ml	Factor IX E/ml
0 h	0	0.86	0.33	1.20
	1	0.86	0.45	1.20
	2.5	0.82	0.33	0.46
	10	0.72	0.30	0.44
1 h	0	0.84	0.40	0.76
	1	0.72	0.24	0.92
	2.5	0.68	0.24	0.82
	10	0.47	0.16	0.68
2 h	0	0.82	0.44	0.10
	1	0.64	0.23	0.90
	2.5	0.68	0.22	0.72
	10	0.60	0.15	0.74
4 h	0	0.76	0.38	0.98
	1	0.56	0.16	0.94
	2.5	0.49	0.29	0.82
	10	0.42	0.27	0.64

Table 10: Influence of light and MB on the activities of coagulation factors: dependence on time and MB-concentration

Example 10

In accordance with a preferred embodiment of the subject invention the photoinactivation of viruses may be effected directly in the plasma bag. The dye at the required concentration is merely added to the blood or the blood products and then the bag is exposed to light. In this simple way it is possible at any time to treat blood products from individual donors.

In a test three samples of fresh human plasma were thawed. Each sample was then inoculated with 1.5 x 106 PFU VSV within the respective plasma bags. MB at concentrations of 1 and 10 µM, respectively, was added to two samples. A sample was taken from the MB-free plasma and stored in the dark at 4°C as a positive control. Then, the three bags were mounted between two Plexiglas plates to ensure a highly uniform layer thickness of approx. 2.5 cm. In turn, said samples were irradiated by means of a slide projector from a distance of approx. 90 cm. After 4 hours, samples were taken to determine the virus titer and the same was measured by plaque assay on FL-cells. The results listed in Table 11 show that 1 µM MB is already sufficient to reduce the infectious titer of VSV by a factor of more than $3\log_{10}$ by means of a four-hour exposure in the plasma bag. Even in the absence of the dye the exposure resulted in a reduction of the virus titer, although only by about 50%.

Sample	Exposure time (h)	MB Concentration (µM)	Weight of Bag (g)	VSV Titer (PFU/ml)
control	0	0	323	$5x10^3$
1	4	0	323	$2.5x10^3$
2	4	1	289	0
3	4	10	257	0

Table 11: Photoinactivation of VSV in plasma bag

The phenothiazine dyes used for virus inactivation may remain in the blood or the blood products, particularly at the concentrations used here, without side effects occurring. However, they may be removed later by means of dialysis, gel filtration or adsorption.

Of the specified methods the adsorptive ones are of main interest because they require the least effort as to time and technical apparatus, and the respective plasma protein solutions are not diluted.

However, some adsorbing agents are obviously unsuitable, such as the ion exchangers mentioned by Hiatt (Concepts in Radiation Cell Biology, pp. 57-89, Academic Press, New York, 1972) because in addition to the dye they also strongly bind plasma proteins, such as coagulation factors.

Surprisingly, it has now been found that MB and other phenothiazine dyes bind very strongly to a various commercially available separation gels, including those which either do not or only weakly bind proteins. Such adsorbing agents are therefore especially suitable for the later removal of the photo-oxidant. Of the adsorbing agents tested, the following ones may be used for the removal of MB and other phenothiazine dyes.

Adsorbing Agent	Material	Manufacturer or Supplier
Daltosil 75	Modified Silica Gel	Serva, Heidelberg (FRG)
Si 100-Polyol RP 18	Derivatized Silica Gel containing C_{18}-groups	Serva, Heidelberg (FRG)
Kieselgel 40	Silica Gel	Merck, Darmstadt (FRG)
Nucleosil 50 Å pore size	Silica Gel	Macherey & Nagel, Düren (FRG)
Nucleosil 100 Å pore size	Silical Gel	Macherey & Nagel, Düren (FRG)
Vydac SC-201 RP	Glass beads coated with Silica Gel bearing C_{18}-groups	Macherey & Nagel, Düren (FRG)
CPG 40	Controlled pore glass (porous glass beads)	Pierce Europe (FRG)
Bio beads, Amberlite adsorbent resins	Polystyrene DVB (Divinylbenzene), Polyacrylester	Bio Rad, München (FRG) Röhm & Haas, Frankfurt (FRG)

In most cases 2 g of the respective adsorbing agent, used as a batch, were sufficient at a feed concentration of 10 µM to completely extract the dye from a plasma protein solution.

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Two types of adsorbing agents proved to be particularly suitable:

1. Silica gels having pores of so small a size (40 to approx. 100 Å diameter) that plasma proteins cannot penetrate the gel matrix while the low molecular weight dye molecules can do so and are thus bonded thereto due to ionic, electrostatic and hydrophobic interaction.

Examples of commercially available adsorbing agents of this type are Matrex Silica Gel (Amicon, Witten), Daltosil (Serva, Heidelberg) and Kiesel-Gel (Merck, Darmstadt).

2. Gels of the type based on polystyrene divinyl benzene and acrylic ester polymer, respectively. They, too, are manufactured with suitable pore sizes.

Examples of commercially available gels of these types are Amberlite (Röhm & Haas, Frankfurt, among others) and Bio Beads (Bio Rad, München). They are mainly used to remove non-polar substances or surface-active agents such as detergents from aqueous solutions. They are either non-polar or only slightly polar.

Example 11

Methylene blue(10 µM) was added to fresh plasma. 5-ml aliquots received varying amounts of Daltosil (pore size 75 Å) and Bio Beads SM16 (pore size 144 Å), respectively, and were then stirred for 30 minutes. Then the gel was left to settle. In the plasma the factor VIII and factor V contents, extinction at 660 nm and, for some samples, the protein contents were measured.

		E (660 nm)	Protein (mg/ml)	Factor VIII (U/ml)	Factor V (U/ml)
Fresh plasma		0.909	66.8	1.10	1.20
Fresh plasma + MB		1.450	65.6	0.42	0.96
Daltosil	50 mg	0.576	—	0.60	1.05
	100 mg	0.571	—	1.10	1.10
	250 mg	0.491	—	1.10	1.20
	500 mg	0.477	66.8	1.25	1.20
Bio Beads SM 16	50 mg	0.666	—	0.82	1.05
	100 mg	0.571	—	1.05	1.10
	250 mg	0.571	—	1.05	1.10
	500 mg	0.530	72.5	0.80	1.15

Table 12: Extraction of methylene blue

It is evident from the extinction values that apparently further substances in addition to the dye are extracted from the plasma. But these substances are not plasma proteins. The extinction values of the plasma which had been treated with 100 to 250 mg of adsorbing agent per 5 ml, i.e. with 2 to 5 weight percent (% w/v), hardly differ from those which had been extracted with 10% w/v adsorbing agent. Hence, at an MB concentration of 10 µM 2 to 5% w/v of adsorbing agent are sufficient in both cases for removing the dye from the plasma in a batchwise operation. If the feed concentration of the dye is lower, the amount of adsorbing agent required is correspondingly lower.

Example 12

In a further test a 5% human serum albumin solution (5% HSA) was used instead of blood plasma. Again, the MB concentration was 10 µM. Aliquots of 5 ml were extracted batchwise with 100 mg, respectively, i.e. 2% w/v, of the following adsorbing

agents for varying periods of time: Daltosil (pore size 75 A Kiesel-Gel (pore size 40 A) and Bio Beads SM16 (pore size 144 A).

As Figure 1 shows, the extinction at 660 nm decreases to a constant value in all three cases within a period of 20 to 30 minutes, i.e. this time period is sufficient to remove the photooxidant in batches from a plasma protein solution. As is further evident from Figure 1, Bio Beads SM16 and Kiesel-Gel 40 appear to be somewhat better adsorbing agents in the subject case than Dalto sil with a pore size of 75 A.

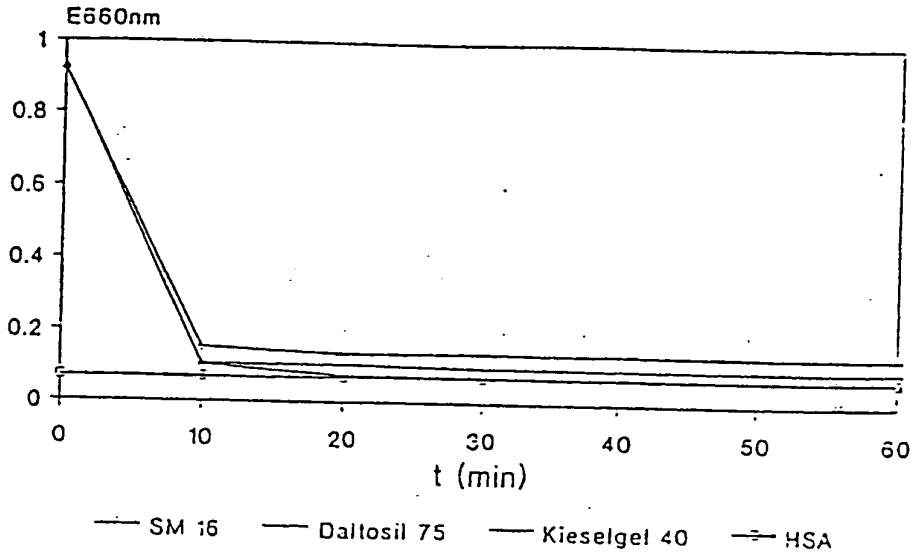

Fig. 1: Adsorbtion kinetics of methylene blue (10 µM) at RT with HSA 5% 100 mg gel/5 ml HSA

Example 13

Removal of MB from plasma protein solutions by column chromatography

The aim of this test was to find out whether or not the adsorptive removal of the photo-oxidant can also be effected by chromatography. This was based on the idea of carrying out the virus inactivation by means of a dye in combination with light in a container, such as a blood bag, and in turn transfering the plasma protein solution to another container, such as a second blood bag, via a small separating column interposed between said containers, and containing the adsorbing agent. If the assembly, comprising the first bag, the adsorbing column and the second bag were prefabricated so that a closed system were available, it would be possible in a very simple way and at the minimum risk of contamination to produce virus-inactivated plasma protein preparations, including from single donor units.

To this end 250 ml of 5% albumin solution were passed at varying flow rates through a separating column containing 5 ml of Kiesel-Gel (pore size 40 Å). Fractions of 10 ml each were collected and their extinction was measured at 660 nm.

As can be seen from Table 13, the overall volume of the albumin solution could be passed through the column at flow rates of 5 and 7.5 ml/min, respectively, and no MB residues could be detected in the fractions coming off the column. Hence, the time required for removal of the dye from 250 ml of solution is only 30 to 35 minutes at most.

The test result shows that the removal of the photo-oxidant by chromatography may be effected without any problems, and also proves that the above-mentioned production of virus-inactivated plasma protein preparations from single donor units is indeed possible.

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Starting Material + MB		Flow Rate (ml/min)	
		5	7.5
extinction (660 nm):	0.067	extinction	(660 nm)
fraction No.	1	0.002	0.001
	3	0.000	0.001
	5	0.000	0.002
	7	0.002	0.003
	9	0.001	0.001
	11	0.000	0.001
	13	0.000	0.001
	14	0.002	0.001

Table 13: Chromatographic separation of MB from a 5% albumin solution (1 µM MB concentration)

CLAIMS:

1. A process for inactivating viruses in blood and blood products, comprising: adding phenothiazine dyes to the solutions or suspensions to be treated and subsequently irradiating said phenothiazine dye containing solutions or suspensions with visible light in the range of the absorption peak of the respective dye, whereafter the blood or blood products may be passed over adsorbing agents for removal of the dyes, characterized that the phenothiazine dyes are used at a concentration of from 0.1 to 2 µM and irradiation is effected directly in transparent containers used for collecting and storing blood.

2. The process as claimed in claim 1, characterized in that toluidine blue or methylene blue is used as the phenothiazine dye.

3. The process as claimed in any one of the claims 1 or 2, characterized in that the solutions or suspensions to be treated are initially subjected to deep-freezing and are then thawed prior to irradiation.

4. The process as claimed in claim 3, characterized in that the dye is added prior to the deep-freezing step.

5. The process as claimed in claim 3, characterized in that the dye is added after thawing and prior to irradiation.

6. The process as claimed in any one of the claims 1 to 5, characterized in that said process is carried out using two containers suitable for collecting blood, such as blood bags,

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with a separating column interposed between said containers, and containing the adsorbing agent for the phenothiazine dyes.

7. The process as claimed in claim 6, characterized in that the adsorbing agents used are silica gels or such agents based on polystyrene divinylbenzene or acrylic ester polymers.

8. A process according to any one of claims 1 to 7, wherein said containers are blood bags.

A PROCESS FOR INACTIVATING VIRUSES IN BLOOD AND BLOOD PRODUCTS

ABSTRACT

The invention is directed to a process for inactivating viruses in blood and blood products, comprising: adding phenothiazine dyes to the solutions or suspensions to be treated and subsequently irradiating said phenothiazine dye-containing solutions or suspensions with light. The use of a very small concentration of phenothiazine dyes prevents any adverse effects on the plasma proteins. Inactivation is effected by direct irradiation of the blood bags.

After irradiation the dyes may be removed from the blood. To this end the blood is passed over adsorbing agents.

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